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Investigations on API Modified Thread Compound Properties with Respect to Sealing Capacity of Open Type Threads

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Abstract

The sealing mechanism of API round thread includes the use of thread compound which is used to seal leak passages. These leak passages are helical capillaries found at the roots and crests of the thread tooth and vary in area according to the size of the thread tooth as well as thread tolerances. The thread compound viscosity is a critical parameter to achieve maximum sealability. This study measured the viscosity of thread compound under various temperatures. It was found that viscosity of thread compound falls in the range of 285,667 cP and 47,758 cP when measured between 32.9 0F and 121.5 0F. This information is very important because thread compound is essential to the function of open thread connections. The investigations were focused on API Modified Compound since it is widely used in the industry. Additionally the compound was analyzed chemically and physically to find a way to correlate the viscosity with compound composition.

Key words: *OCTG, Thread, Compound*

Introduction

American Petroleum Institute (API) Round thread connections have been extensively used for “low cost” wells mainly because they are cheap, simple, and easy to manufacture. Their two main functions are to provide structural integrity by keeping the pipe sections attached to form a continuous length and to provide sealing integrity by maintaining leak tightness against internal and external fluids while subjected to loads of assembly interference, axial tension or compression, internal and external pressures, and bending. The sealing mechanism of API round thread includes the use of thread compound which is used to seal leak passages. These leak passages are helical capillaries found at the roots and crests of the thread tooth and vary in area according to the size of the thread tooth as well as thread tolerances. The thread compound viscosity is a critical parameter to achieve maximum sealability. This study measured the viscosity of thread compounds under various temperatures. It was found that viscosity of thread compound falls in the range of 285,667 cP and 47,758 cP when measured between 32.9 ^{0}F and 121.5 ^{0}F. This information is very important because thread compound is essential to the function of open thread connections. The investigations were focused on API Modified

Compound since it is widely used in the industry. Additionally the compound was analyzed chemically and physically to find a way to correlate the viscosity with compound composition.

Thread Compounds for Oil Country Tubular Goods (OCTG)

The typical thread compounds for very OCTG are formed using base grease in which solid particles are dispersed. The grease is standard lubricating grease, made of mineral oil and having a metal soap as thickener (i.e. aluminum stearate). Additives are added in low amount to the compound to improve the following properties: high pressure resistance, wear protection, corrosion protection, etc.

The role of the solid particles is to provide anti-galling resistance and sealing properties of the compound. Powdered metals and non-metallic particles like graphite or ceramic spheres are used as solid ingredients. Typical metals used for thread compounds manufacturing are: lead, copper, zinc. The common non-metallic solids used for compounds are graphite, PTFE, ceramics.

The so called “green dope” or environmental friendly compounds have a totally metal-free composition.

According to [1] the performance general requirements of the thread compounds include: consistent frictional properties, adequate lubrication and sealing properties, physical and chemical stability both in service and in storage conditions, and properties that allow the efficient application of the compound on the connection surfaces. In addition, the thread compounds for Rotary Shouldered Connection should lubricate the connection during the make-up runs to achieve bearing stresses (buck-up force). The sealing capacity or, according to some authors, leak tightness, is provided by the high viscosity of the thread compound and the small free path inside of the threaded connection. Every commercially available thread compound has its own characteristics that are measured and reported. **Figure 1** shows such report as given in the product specifications. It must be noted that the thread compound viscosity is not reported for OCTG compounds. In a previous paper [2] we showed the typical composition of API thread compounds as well as deformation mechanism that takes place inside of the thread compound.

Sealing Mechanism of Open Threads

When an open thread type is used (like API round or Buttress) the thread is an open helix that can be sealed by a means of a high viscous material like thread compound. Once the compound is placed in the thread gaps, a certain force is required to move (push) the compound through the helix. To achieve a good seal the thread compound must have high viscosity, but in the same time the viscosity must not exceed a certain value in order to allow the brushing ability (smooth and uniform thread compound application on the thread).

Figure 2 shows the common gap inside of an API round thread that must be sealed by the thread compound. Between threads a small gap remains which must be filled in order to provide a leak tight connection. This space is filled by the thread compound that is applied on pin and box before make-up. As it can be seen in the Figure 2 the leak path consists of two spiral spaces comprising the gaps between pin thread crest and box thread root and pin thread root and box thread crest, respectively. The gap size depends on the thread manufacturing tolerances, having a maximum area of 0.155 mm^2 per helix [5].

Table A.3 — Modified thread compound control and performance tests

Test	Requirement
Penetration, mm × 10 $^{-1}$ worked at 25 °C (NLGI [a] Grade No. 1) after cooling at –18 °C (see procedure annex C)	 310 to 340 200 min.
Dropping point, °C (ASTM D 566)	88 °C min.
Evaporation, % mass fraction 24 h at 100 °C (see annex D)	 2,0 max.
Oil separation, % mass fraction, nickel cone 24 h at 66 °C (see annex E)	 5,0 max.
Gas evolution, cm^3 120 h at 66 °C (see annex G)	 20 max.
Water leaching, % mass fraction after 2 h at 66 °C (see annex H)	 5,0 max.
Brushing ability (see annex F)	Applicable at –18 °C

[a] National Lubricating Grease Institute, 4635 Wyandotte Street, Kansas City, MO 64112-1596, USA.

NOTE The information presented in this table applies only to the API modified thread compound formula.

Fig. 1. API modified thread compound characteristics as reported in product specifications, after [3]

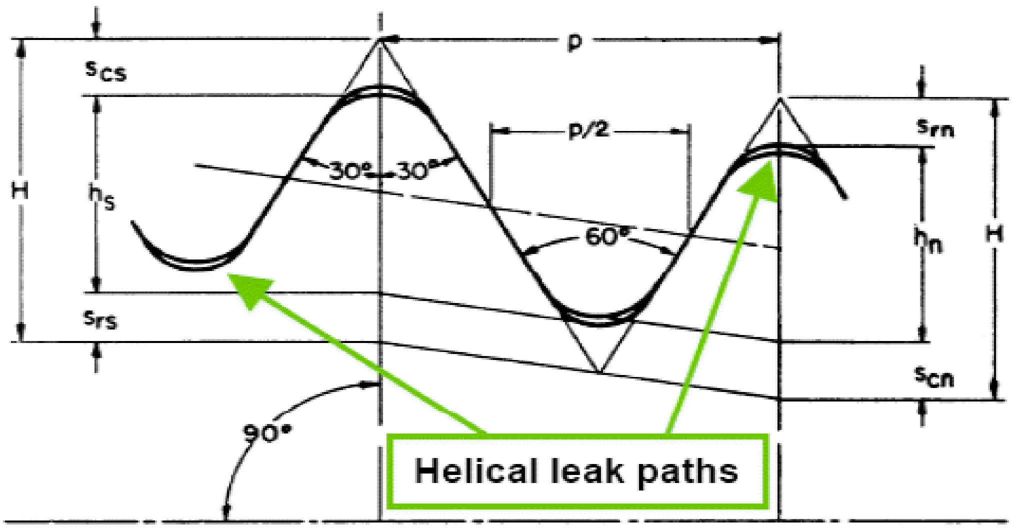

Fig. 2. Detail view of API Round thread geometry showing the helical leak paths

Experimental Data Related to Thread Compound Viscosity

To measure the viscosity of the available thread compound samples, the Brookfield DV-III Ultra programmable rheometer was used. It was designed specifically for the measurement of fluid parameters of shear stress and viscosity at given shear rates. According to the operating instructions manual [4] the viscosity drag of the test fluid against the spindle is measured by the deflection of a calibrated spring. The rotational speed of the spindle, along with its size and shape can affect the viscosity measurement. Additionally, some types of fluids are considered to be thixotropic. The viscosity of a thixotropic material decreases under constant speed over a period of time. The viscosity of thread compounds was found to follow this behavior during initial practice runs and adjustments were made to the procedure to standardize results.

For this experiment one thread compound sample have been used: API Modified Thread compound, which is widely used across the oil industry.

To measure the viscosity of thread compound a basic procedure was followed. This procedure is a combination of the procedure set forth by the standard ASTM D 2196 and that described by the Brookfield operating manual for the Brookfield DV-III Ultra programmable rheometer. This simple procedure was then combined with different loads such as temperature and time to provide an idea of the viscosity of thread compound under different conditions.

To provide a viscosity measurement over a wide range of temperatures, the rheometer was hooked up to a water bath capable of providing a wide range of temperatures, see figure 3.

For each temperature a minimum of three measurements have been performed in order to generate a statistical data base. Seven temperatures have been selected to generate the viscosity behavior versus temperature.

Additionally several standard properties as reported in Figure 1 have been also measured. The main parameters are: dropping point, evaporation and density.

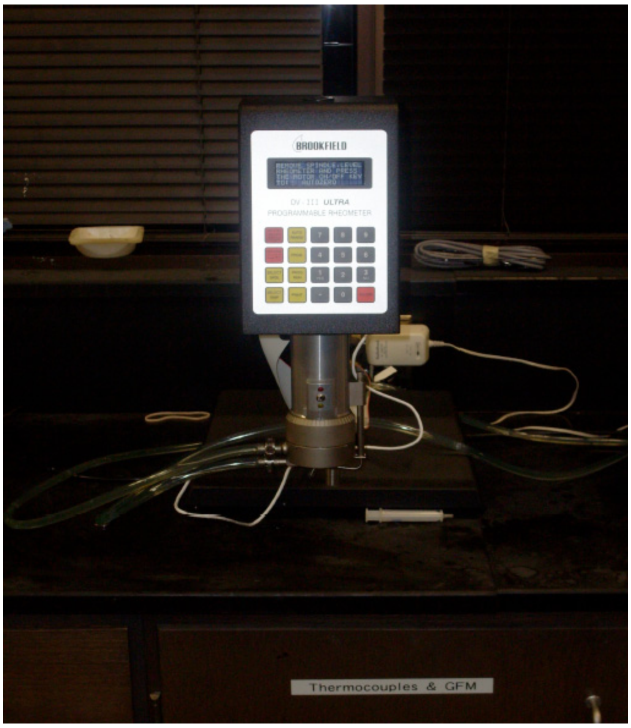

Fig. 3. Picture showing the experimental setup of Brookfield viscometer

Results and Discussions

Table 1 shows the results obtained from carrying out the basic procedure for testing the viscosity of API Modified thread compound. Measurements were done three times and arithmetic mean found to give an average value. The Brookfield Rheometer also measures other parameters while taking viscosity measurements. The shear stress and torque are the other quantities measured by the rheometer along with the viscosity, while temperature is varied.

Table 1. Measured Viscosity as a Function of Temperature

Temperature	Shear Stress	Torque	Viscosity
32.9	11,430	72	285,667
50.4	7,255	46	181,667
67.9	5,736	36	143,333
85.8	4,651	29	116,333
103.9	4,212	26	106,000
121.5	3,778	24	94,854
139.5	3,075	19	76,730

Note that the temperature is reported in Fahrenheit.

After plotting the viscosity data versus temperature it was found that there is an exponential relationship between the two parameters. The exponential curve used to fit these data is shown in the Figure 3. This fitted curve allowed us to extrapolate the viscosity behavior up to 260 F which covers the range of most common oil and gas reservoir (this does not include High Pressure High Temperature reservoirs).

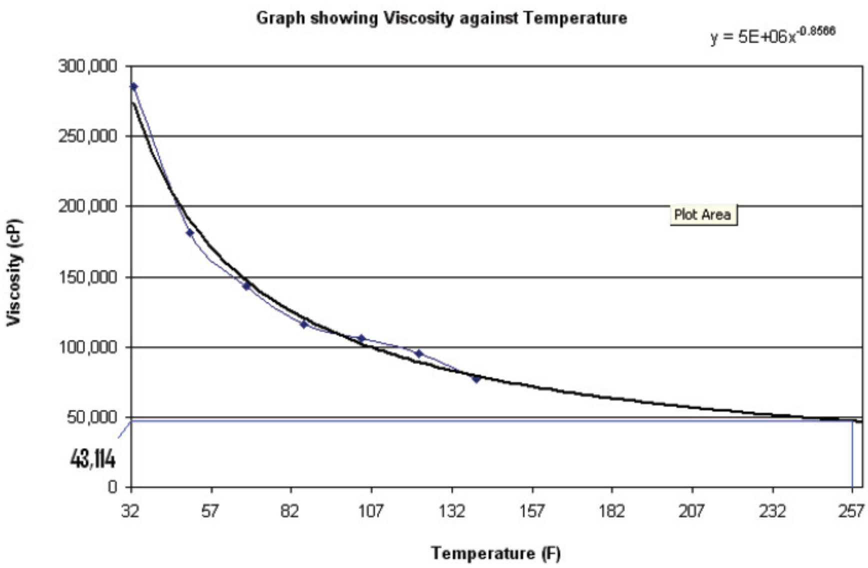

Fig. 3. Viscosity of API Modified thread compound as a function of temperature

When the thread seal relies only on the thread compound, the sealability at temperatures above 100 F (37 C) may be affected due to low compound viscosity. On the other hand, low temperature will affect the thread compound ability to flow inside of the thread compound producing negative effects like dope pressure inside the thread.

The dropping point measured for the API Modified thread compound was 138^{0}C (280F) while the reported API compound dropping point is 88^{0}C (190F).

Conclusions

The thread compounds used for OCTG threaded connections play an important role to seal and lubricate them.

It has been found that the thread compound viscosity is strongly affected by the temperature, showing an exponential behavior. Within a normal operating range of temperature the viscosity will vary from 300000 cP to 100000 cP.

This preliminary study of thread compound viscosity will allow for the future the development an analytical approach to calculate the seal capacity of threaded connections.

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Studiul experimental al unsorii “API Modified” cu privire la capaciatea de etansare a imbinarilor filetate

Rezumat

Unsorile pentru filete sunt folosite in industria petroliera in scopul imbunatatirii si optimizarii procesului de insurubare a materialului tubular petrolier, cunoscut sub numele de OCTG. Mecanismul de etansare al filetelor se bazeaza pe introducerea unei substante viscose in spatial elicoidal genrat de geometria imperfect a filetului.Viscositatea unsorii este foarte importanta atunci cind se analizeaza capacitatea de etansare a unei imbinari filetate. Lucrarea de fata prezinta investigatiile experimentale asupra unsorii API Modified. A fost masurata viscositatea unsorii la temperature intre 32.9^{0}F si 121.5^{0}F obtinindu-se valori intre 285667 cP and 47758 cP.